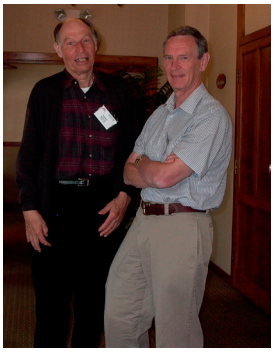
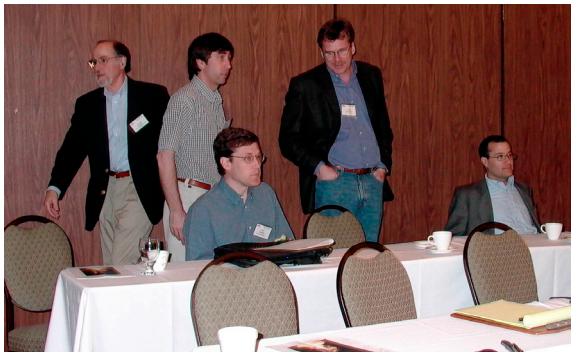
CHAPTER 1 WE LAUNCH PHYSICS FOR EXPLORATION AT NASA

Launch of Gravity Probe B from Vandenberg Air Force Base during the workshop



2004 NASA/JPL Workshop on Physics for Planetary Exploration














New Directions for Fundamental Physics Research

by Bob Silberg, Raytheon

The primary focus of the workshop was NASA's new concentration on sending crewed missions to the Moon by 2020, and then on to Mars and beyond. Several speakers, including JPL's Fred O'Callaghan and NASA's Mark Lee, broached the problem that there is now a serious reduction of capability to perform experiments in the ISS, or to fly significant mass in microgravity by other means. By 2010, the shuttle fleet will be discontinued and Russian craft will provide the only access to the ISS.

O'Callaghan stated that the Fundamental Physics budget is being reduced by 70%. LTMPF and LCAP are slated for termination. However, ground-based experiments are continuing to be funded at present, and it will be possible to compete for $80-90 million in new money from the Human Research Initiative (HRI).

The new program thrust is for exploration, not fundamental physics. "Fundamental," we were told by Lee, does not ring well in Washington these days. Investigators were advised to consider how their work can benefit missions to the Moon and Mars. Work such as that regarding atomic clocks is looked upon with favor, for example, because it is considered important to navigation and planetary GPS.

Mark Lee stressed that physicists must convey to NASA senior management that they are able and willing to contribute to the new exploration research programs. The new mentality must be "we deliver products, not do research." This program needs to be able to say that it is doing at least 50% exploration-related research.

JPL's Ulf Israelsson discussed the implications to OBPR, which will deliver methods and technology to assure human health and performance in extraterrestrial settings. The enterprise will provide advanced life-support systems and technology that are reliable, capable, simpler, less massive, smaller, and energy-efficient, and it may offer other necessary expertise in areas such as low-gravity behavior. Like Dr. Lee, he stated that the focus must be on products, not research.

While there is not yet a formal direction, he said, LTMPF and PARCS ISS flight projects are slated to terminate in October 2004. All flight investigations are being returned to ground programs and phased out by the end of FY07. Physics ground programs are intact for now, but to survive we must shift about 50% of research to supporting exploration. Basic research programs in other disciplines are being cancelled.

Product lines will support human health, safety and life-support, including countermeasures against radiation and other hazards, as well as advances in time-keeping, navigation and communications technologies.

Israelsson said that the new Fundamental Physics for Exploration Roadmap points to how fundamental physics research can and does support exploration. JPL will use the roadmap to argue for support for fundamental physics research under several codes.

Nicholas Bigelow of the University of Rochester encouraged attendees not to become discouraged, but rather to embrace the opportunities presented by NASA's new direction.

*Physics in NASA Exploration**

Fred O'Callaghan
Astronomy and Fundamental Physics Office
Jet Propulsion Laboratory, California Institute of Technology

- New direction for NASA Moon and Mars and beyond
- Reduction in up/down mass to ISS
- ISS flight experiments transition to ground
- Program thrust for exploration away from fundamental physics research
- Ground investigations will continue
- Atomic clock work important to navigation (planetary GPS)
- Applied Physics will be needed for Moon/Mars Missions
- Many challenging problems will need to be solved
- NASA will continue to stress education and research
- The future is in your hands, your postdocs, grad students, all the way down to the unborn

*Research performed at the Jet Propulsion Laboratory, California Institute of Technology, under a grant from the National Aeronautics and Space Administration

O
B
P
R

Status of Fundamental Physics Program

Presented to the
Fundamental Physics Workshop
Solvang, California

April 20-22, 2004

Mark C. Lee

Update of the Fundamental Physics Program

OBPR

❖ Moon-Mars Initiative

- New direction for the nation's civil space program
  - Implement a sustained and affordable human and robotic program to explore the solar system and beyond
  - Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
  - Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and
  - Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

- Exploration becomes NASA's primary focus
  - Fundamental research de-emphasized;
  - LTMPF and LCAP are slated for termination; but
  - Fundamental Physics ground-based program is retained; however
  - We must demonstrate our WILLINGNESS and ABILITY to contribute to the Exploration Research;

Update of the Fundamental Physics Program continues…

OBPR

- Budget reduced by 70%;
- Need to REFOCUS (O'Callaghan)
  - Contribute to OBPR Product Lines (~50%)
    - Partial gravity research (Valles)
    - Precision navigation/landing (Phillips/Sullivan)
    - Remote sensing (Kasevich)
    - SQUID sensor applications (Chui)
    - …
  - Compete for Human Research Initiative (HRI) Augmentation (Israelsson)

❖Research Solicitation

- Tentatively plan to issue before December 31, 2004
- Bridge funding

❖New FP Roadmap (DWG/Bigelow & Israelsson)

OBPR Product Lines, Human Research Initiative, and Physics Roadmap for Exploration

April 20, 2004

Ulf Israelsson

Jet Propulsion Laboratory
California Institute of Technology

This research was performed at the Jet Propulsion Labotory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

AGENDA

JPL

- *Changes since last year*
- *OBPR Product Lines*
- *Human Research Initiative*
- *Fundamental Physics for Exploration Roadmap*
- *Conclusions*

Changes since last year

- *OBPR Implications from President's Exploration Vision*
  - *OBPR WILL deliver methods and technology to assure human health and performance extra-terrestrially*
  - *OBPR WILL deliver advanced life-support systems and technology that are reliable, capable, simpler, less massive, smaller, and energy efficient*
  - *OBPR MAY provide other necessary expertise in areas such as low-gravity behavior*
- *Focus on products – not research*
- *No FORMAL direction yet, but..*
  - *LTMPF and PARCS ISS flight projects slated to terminate in October 2004*
  - *All flight investigations returned to ground program and phased out by end of FY07*
  - *Physics ground program intact – for now, but to survive must shift ~ 50% of research to support exploration*
- *Other disciplines basic research program being cancelled*

- **Human Health and Countermeasures**
  - Guy Fogleman, NASA HQ Point of Contact
- **Human Life Support Systems**
  - Eugene Trinh, NASA HQ Point of Contact
- **Radiation Protection and Countermeasures**
  - Terri Lomax, NASA HQ Point of Contact

- ***Exercise Systems***
- ***Behavioral Health***
- ***Pharmacology Immunology Nutrition***
- ***Artificial Gravity/Gravity Thresholds***
- ***Technology for Research***
- ***Autonomous Medical Care***
  - ***Monitoring***
  - ***Prevention***
  - ***Diagnosis***
  - ***Treatment***

- *Advanced Life Support (ALS)*
- *Advanced EVA Systems (AEVA)*
- *Advanced Environmental Monitoring & Control (AEMC)*
- *Advanced Food Technology (AFT)*
- *Space Human Factors*
- *Fire Prevention, Detection, and Suppression*
- *In Situ fabrication and Repair*
- *In Situ Resource Utilization*

- ***Mission & Operations Requirements***
- ***Shielding Solutions***
- ***Risk Assessment & Projection***
- ***Biological Countermeasures***
- ***Measurement Technologies***

Identified areas where Fundamental Physics can contribute

JPL

- ***Human Health and Countermeasures***
  - ***Low-gravity simulators to determine gravity thresholds for biological processes and systems***
  - ***Non-invasive medical sensors based on SQUID technology***
  - ***Advanced NMR/MRI concepts***
- ***Human Life Support Systems***
  - ***Remote resource location technology (gravity gradient, magnetic)***
  - ***Advanced Sensor technology***
  - ***Low-gravity simulators to validate designs for Space, Moon, and Mars fluid systems***
- ***Radiation Protection and Countermeasures***
  - ***Neutron detectors and other sensors***
  - ***Low-gravity simulators to investigate possible interactions between low-gravity effects and radiation damage***
- ***Cross-cutting technology***
  - ***Clocks, Navigation, and Communication technology***

Human Research Initiative

JPL

- *New initiative to fill in perceived funding gaps to ensure human safety and productivity in space.*
- *Approximately $90M annually of directed research funding*
- *Solicitation is limited to NASA centers in the first year*
  - *Universities must team with JPL or other centers to participate*
- *Future years solicitations may be more open*
- *Proposals are solicited at a high summary level with points of contacts identified to work through*
  - *Funding expected to be in the $1–10M range*
- *Solicitation released April 1*
- *Proposals are due May 15*
- *Selection process goes through June*
- *Funding start in October*

Fundamental Physics for Exploration Roadmap

- ***Draft Roadmap discussed at last years PI conference***
- ***Initial Roadmap completed in December 2003. Strong community participation.***
- ***Publication was placed on hold pending rumored changes to a NASA exploration focus.***
- ***Following the President's announcement in January, the Roadmap is undergoing some minor changes to point more clearly to how fundamental physics research can and does support exploration***
- ***JPL will use the new Roadmap to argue for support for fundamental physics research not just to Code U, but to Code S and Code T as well***
  - *We enlist the support of the physics community in this endeavor*

JPL

Old Roadmap Goals:

1. ***Discover new physics beyond today's knowledge of fundamental laws governing matter, space, and time***
   - A. *Determine the range of validity of Einstein's relativity theories*
   - B. *Discover evidence for New Physics beyond the Standard Model*
   - C. *Find answers to questions of cosmological significance*
2. ***Understand organizing principles of nature from which structure and complexity emerge***
   - A. *Acquire a deeper understanding of organizing principles in condensed matter systems and incorporate in new advanced technologies*
   - B. *Discover new knowledge about interactions in cold gasses of atoms and incorporate in new advanced technologies*
3. ***Apply physics results to enable technologies that allow human space exploration far beyond what is possible today***
   - A. *Demonstrate benefits of novel physics technologies to solve human space exploration challenges*

Fundamental Physics for Exploration Roadmap

New Roadmap Goals:

1. ***Apply physics technologies to solve today's human space exploration challenges***
   - A. *Develop physics-based advanced communication and navigation products for Moon, Mars, and beyond*
   - B. *Develop physics-based advanced resource-location products for human and robotic exploration in the solar system*
   - C. *Develop physics-based tools for enhanced studies of living systems*
2. ***Understand organizing principles of nature from which structure and complexity emerge and apply to tomorrow's exploration needs***
   - A. *Acquire a deeper understanding of organizing principles in condensed matter systems and incorporate in exploration technologies*
   - B. *Discover new knowledge about interactions in cold gasses of atoms and incorporate in exploration technologies*
3. ***Discover new physics beyond today's knowledge of fundamental laws governing matter, space, and time to enable exploration far beyond what is possible today***
   - A. *Determine the range of validity of Einstein's relativity theories*
   - B. *Discover evidence for New Physics beyond the Standard Model*
   - C. *Find answers to questions of cosmological significance*

Conclusions

- ***The pace of change has increased at NASA***
- ***OBPR's focus is now on the Human interface as it relates to the new Exploration vision***
- ***The fundamental physics community must demonstrate how we can contribute***
  - *If we do, it is likely that our basic research program will continue*
- ***Many opportunities exist for physicists to participate in addressing NASA's cross-disciplinary exploration challenges***
  - *Physicists can contribute to elucidating basic operating principles for complex biological systems*
  - *Physics technologies can contribute to developing miniature sensors and systems required for manned missions to Mars*
- ***NASA Codes other than OBPR may be viable sources of funding for physics research***

Fundamental physics changes in response to evolving NASA needs

April 14, 2003

Ulf Israelsson

Jet Propulsion Laboratory

California Institute of Technology

This research was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

AGENDA

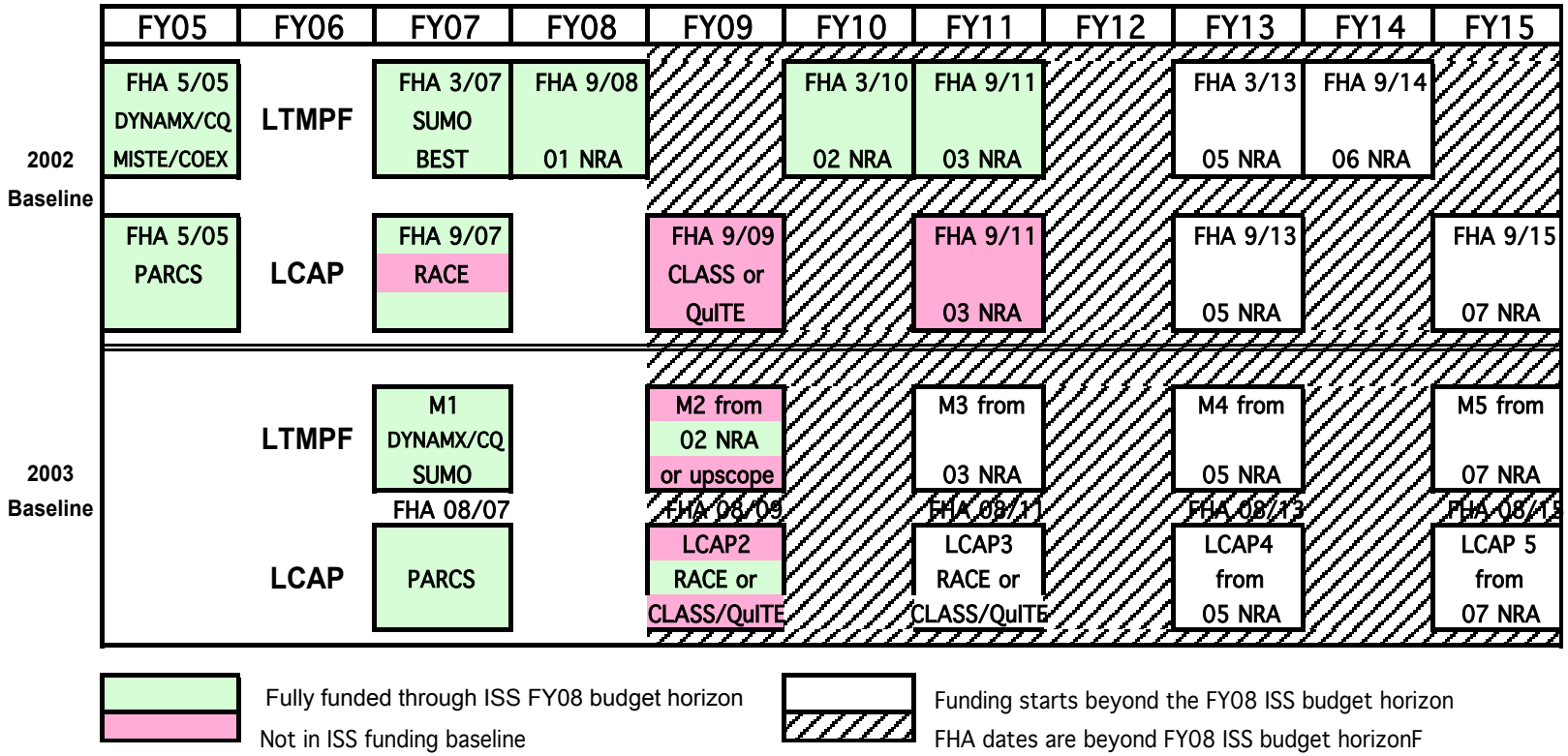
- *Recent NASA Changes*
- *Growing need for access to space for physicists*
- *Rationale for updating the Fundamental Physics in Space Roadmap*
- *Advocacy help from the community*
- *Conclusions*

- **REMAP**
  - **Increased budget pressure from Life Science disciplines**
- **Mary Kicza putting her spin on OBPR**
  - **ISS focus on human- tended research**
  - **Increased importance of Strategic Research**
    - Enabling a safe human presence beyond LEO
  - **Free flyer initiative seeking a FY05 new start**
- **Societal relevance is still important**
- **To measure performance is still a requirement**
- **Columbia disaster**

Recent NASA Changes continued

- **JEM-EF delay has forced a slip of LTMPF and PARCS by 2+ years.**
  - **Budget arbitrarily reduced**
- **LTMPF–M1 re-programmed with SUMO instead of MISTE.**
  - **To maximize science return on first mission**
  - **Desire to link PARCS and SUMO clocks to further enhance science**

Current Fundamental Physics ISS Options compared to 2002 Baseline



Growing need for access to space for physicists

- **Physics is standing at the threshold of major discovery.**
  - **Two of our foundational descriptions of nature, quantum mechanics and general relativity, are incompatible with each other.**
  - **When scientists resolve this conflict, a different view of reality may emerge.**
- **Cosmological observations are providing additional clues that our understanding of reality is in need of modification.**
  - **Most of the energy content of the Universe resides in unknown dark matter and dark energy that may permeate all of space-time.**
- **Resolving the Quantum/gravitation conflict may also shed light on the cosmological unknowns.**
- **Today's availability of high-resolution technology and space access represents a unique opportunity for scientists to address these questions.**
- **Quiescent *sub-microgravity* freely flying research platforms would enhance the chances of major discovery substantially.**
  - **To be discussed on Tuesday afternoon**

Need for Roadmap

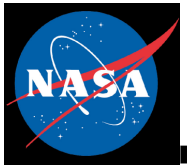
JPL

- To continue growing as a discipline, we need to establish a new vision of where we are going that is consistent with today's physics, NASA's strategic plan, and the new OBPR direction.
- 1998 Roadmap focused exclusively on Physics, and did not worry about boundaries between OBPR and OSS
- Updated Roadmap:
  - Must incorporate some strategic research activities to be fully responsive to the current OBPR direction
  - Must capture the imagination of OBPR leadership, OMB, and Congress.
  - Must delineate OBPR from the "beyond Einstein" program in OSS
  - Must address relevancy to Society explicitly
- Status of the Roadmap development will be discussed after lunch today.
  - Seeking community inputs and endorsement
- Draft update targeted for June, final in August

In addition we must….

JPL

- **Continue to demonstrate research productivity to NASA**
  - **Significant events**
  - **Press releases**
- **Remember that our accomplishments are ultimately evaluated by the scientific community**
  - **Prestigious peer reviewed journals reaching a wide audience**
- **Continue reaching out to students and the general public**
- **Keep thinking about how your technology improvements might be applied to solve human space exploration issues.**
- **Keep thinking about how your technology improvements might be used for Earth applications to enhance national security or promote industrial prowess.**



Conclusions

- **Change continues in the NASA environment**
- **The need for access to space for physicists is growing if we are to fruitfully address today's challenging questions**
- **A new Roadmap is required to demonstrate the importance of our program to stakeholders**
  - Roadmap plans and activities to be discussed after lunch today
- **Our investigators must continue to advocate the benefits of our program:**
  - To NASA and Congress
  - To the scientific community
  - To students
  - To the general public
- **Our investigators must seek ways to use their advanced technology to support a human presence in space and to develop improved Earth applications**

Acknowledgement

The work described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

Japanese research activities in fundamental science

Hiroto Kobayashi

ISS Science Project Office
Japan Aerospace Exploration Agency

Establishment of JAXA

Consolidation of three Space Organizations:

ISAS (Institute of Space and Astronautical Science)

NAL (National Aerospace Laboratory of Japan)

NASDA (National Space Development Agency of Japan)

↓

Establishment of

JAXA (Japan Aerospace Exploration Agency)

(October 1, 2003)

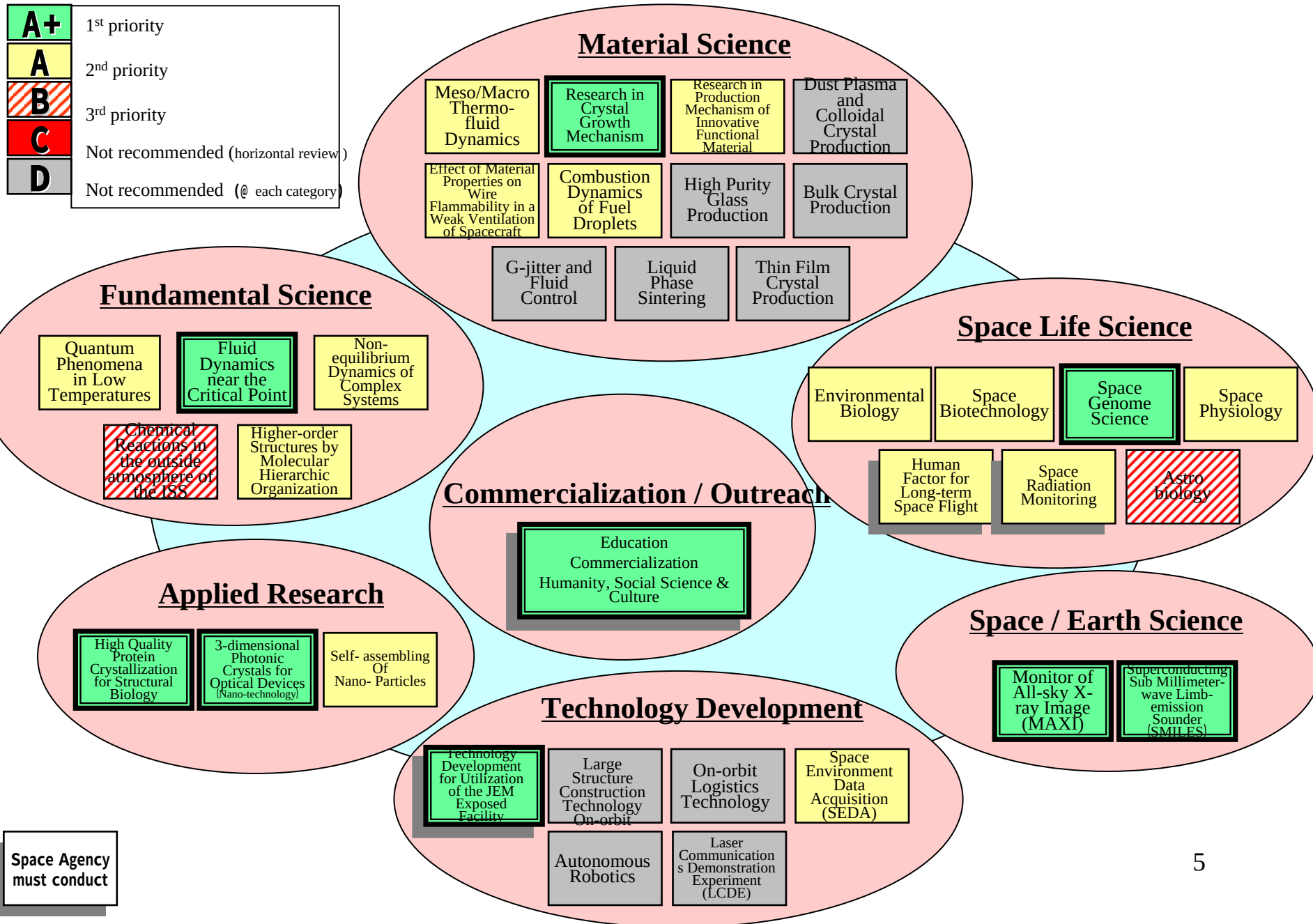
ISS/JEM Utilization Prioritization in Japan (June 2003)

Background of the Activity

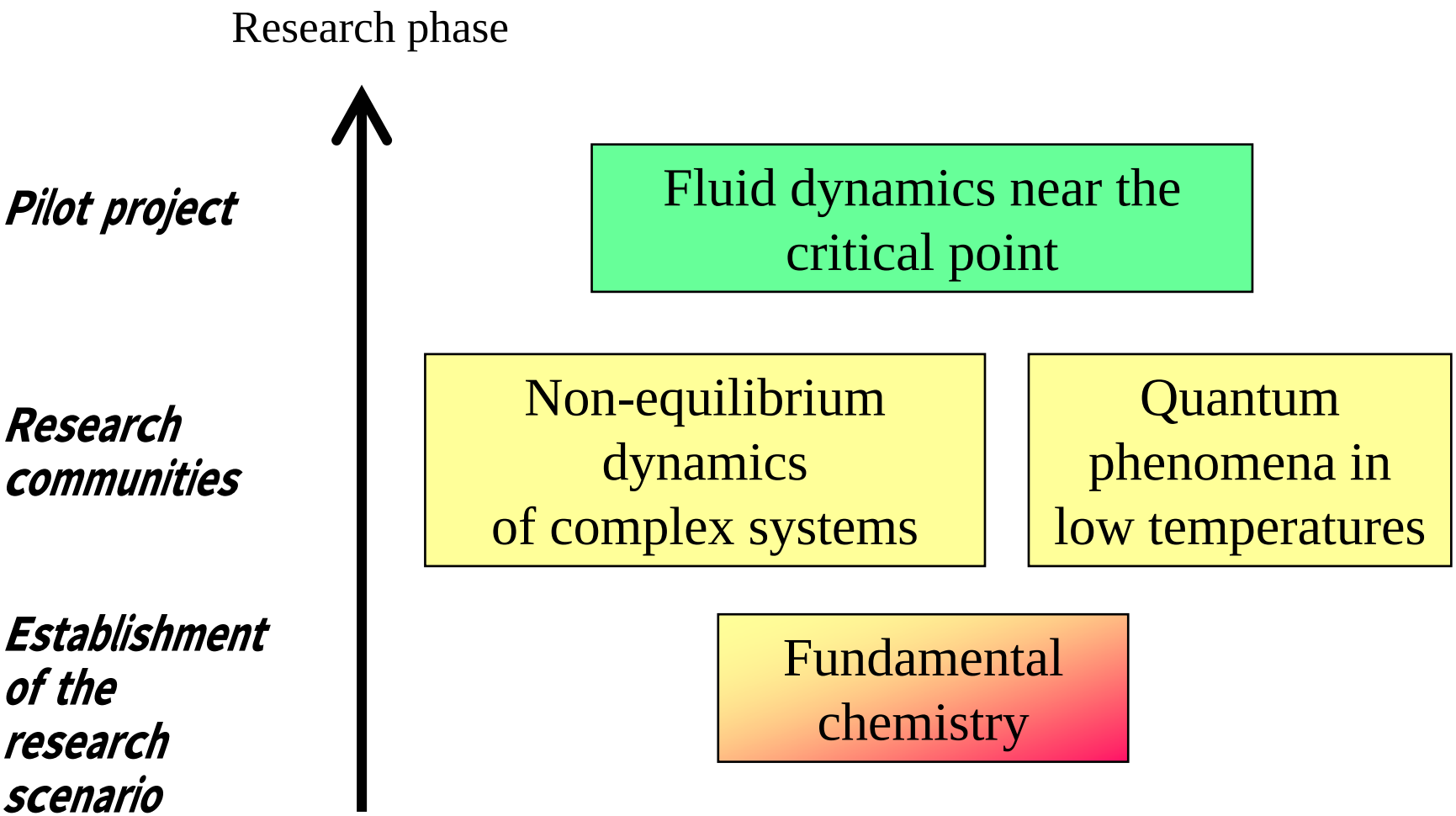
- SAC* recommended MEXT/NASDA to re-plan Japanese ISS/JEM program, especially utilization plan to adapt recent circumstances (below) of ISS/JEM program June 2002.
  - Re-planning of ISS program in the U.S.A.
  - National financial situation
  - Expansion of space utilization to various fields
  - Consolidation of three Space Organizations (NASDA, ISAS, and NAL)
- SAC established ISS Utilization sub-committee under itself, and NASDA established ISS/JEM Utilization Prioritization Ad hoc Committee and ISS/JEM Utilization Promotion Ad hoc Committee.
- NASDA's committees conducted preliminary study to provide a basis for discussion at ISS Utilization sub-committee.
  - Prioritization of early phase utilization of ISS/JEM
  - Re-structuring utilization promotion system
  - Exploring corporation with private sector in JEM operation and utilization activities
- After a few months discussion, ISS Utilization sub-committee issued an interim report to SAC June 2003.

*)The Space Activities Commission of the Ministry of Education, Culture, Sports, Science and Technology

Prioritization of JEM/ISS Early-phase Utilization



Research phases of prioritized areas in fundamental science



Establishment of Research Scenario in Fundamental Physics and Chemistry

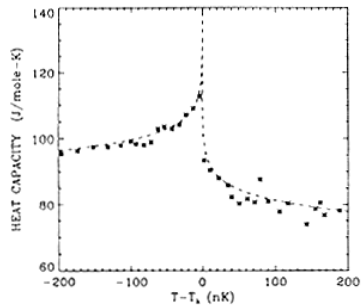
Research Scenario of Fundamental Physics in Microgravity

Nonlinear Phenomena & Non-equilibrium Thermodynamics

- Reaction-diffusions system
- Pattern formation
- Phase transition of complex fluids
- Laser Trapping of liquid drops
- Macromolecular reactions

Fluid dynamics Near Critical Point

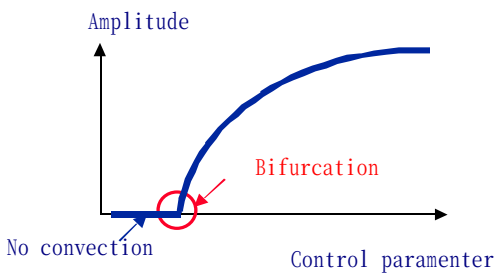
- Relaxation dynamics under piston effect
- Nucleation and boiling
- Critical self-organization



Microgravity Sciences

Fluctuations & Correlations in Many Body Systems

Fundamental Physics & Chemistry

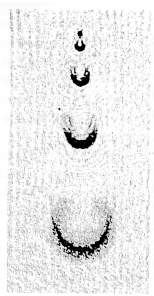


Mathematical Modeling of Fluctuations & Correlations

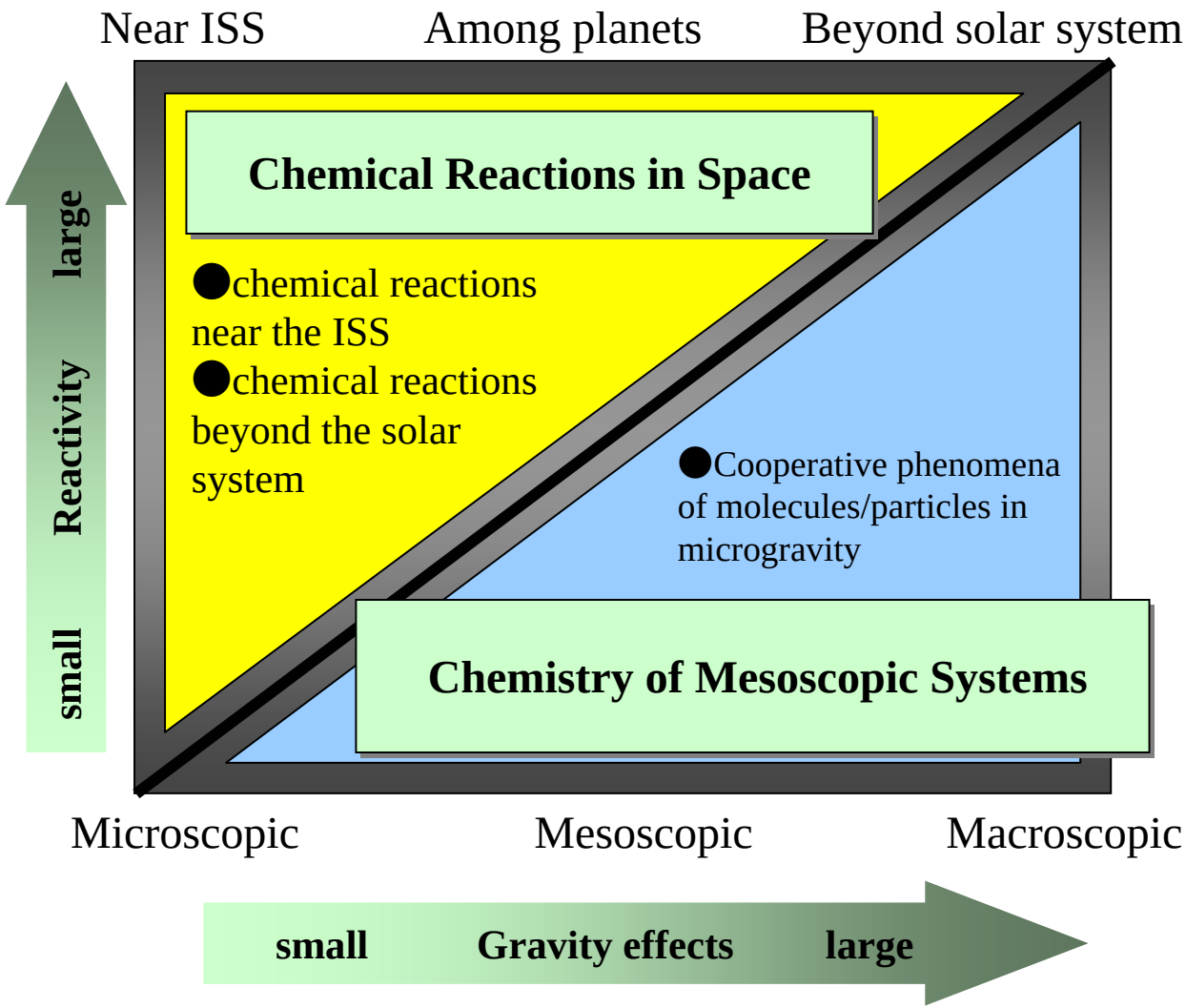
- Spontaneous symmetry breaking & bifurcation
- Renormalization group & universality
- Mode coupling theory
- Stochastic resonance
- Nonlinear mathematics

Macroscopic Quantum Phenomena

- BEC
- Quantum nucleation
- Quantum crystal growth
- Quantum coherency



Research map of fundamental chemistry



Ground-based experimental project in JAXA (Piston Effect)

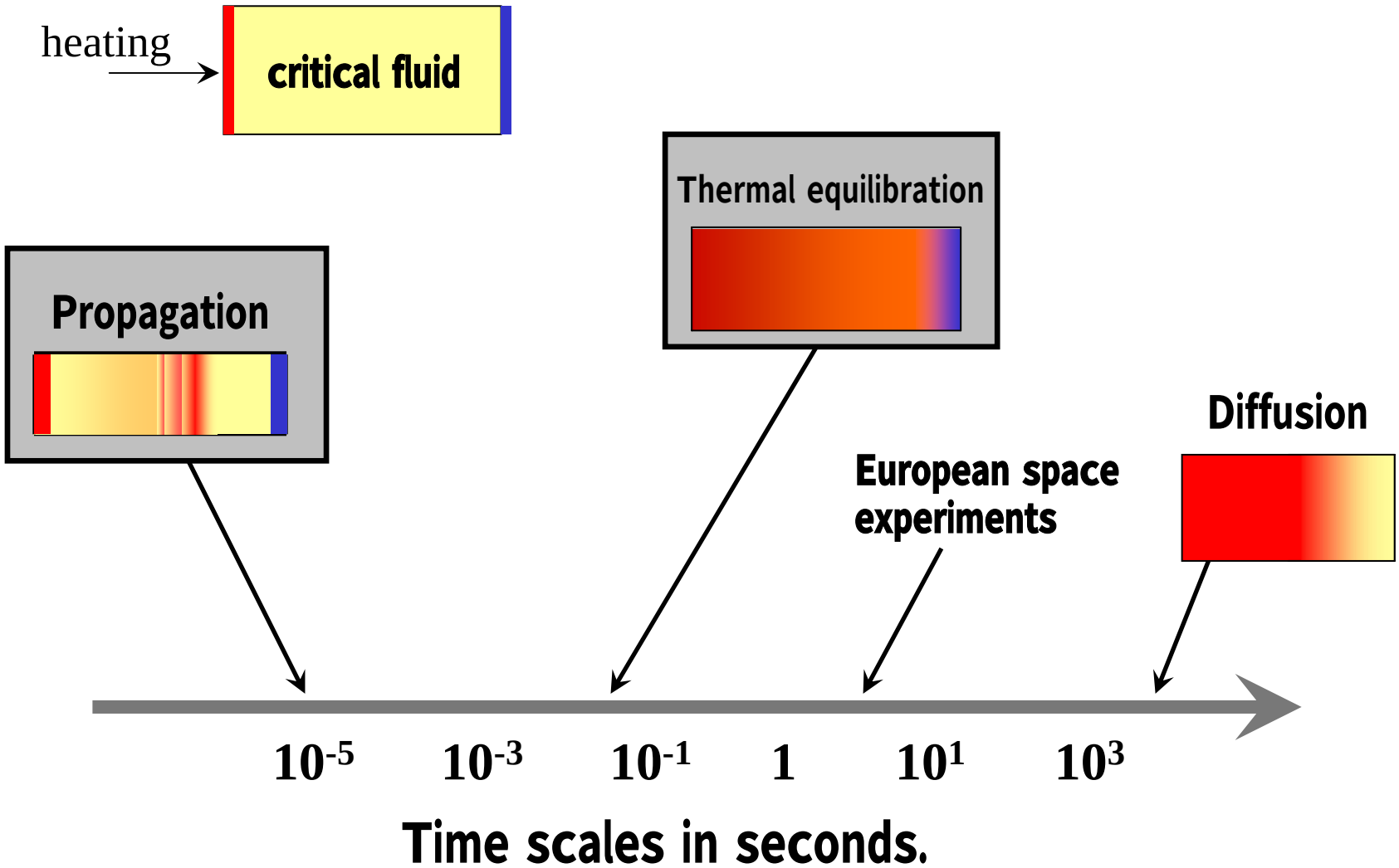
Summary of results

1) **Elementary processes of the piston effect were first observed using critical CO_2.**
2) **Piston wave attenuates faster as the critical point is approached.**

Piston effect

= Rapid thermal equilibration of critical fluids

Time scales in the ‘piston effect’



Experiments

Experimental procedure:

pulse heating => sound wave propagation

=> density variation

=> optical measurements

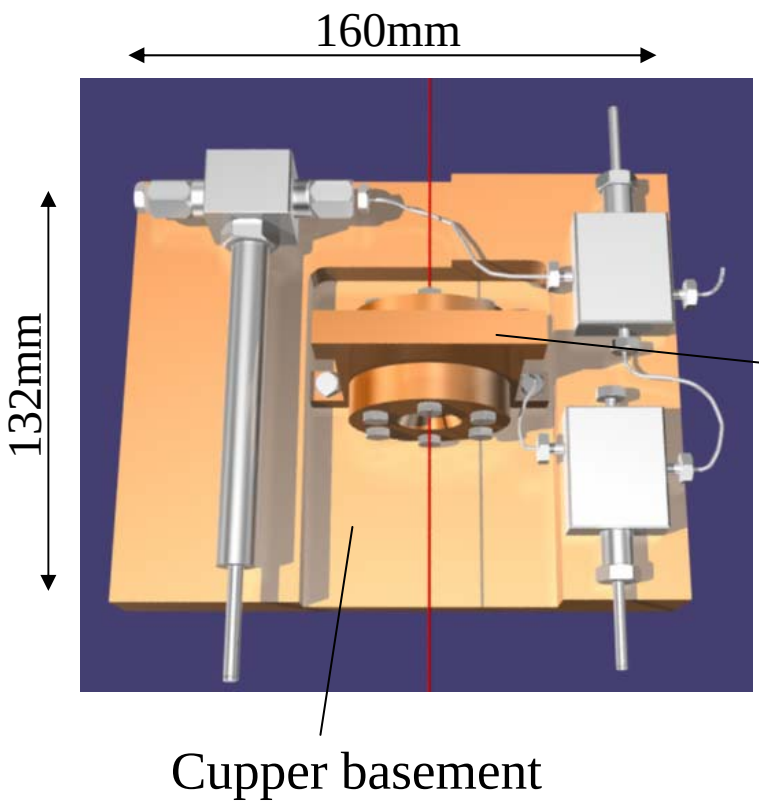
Experimental apparatus

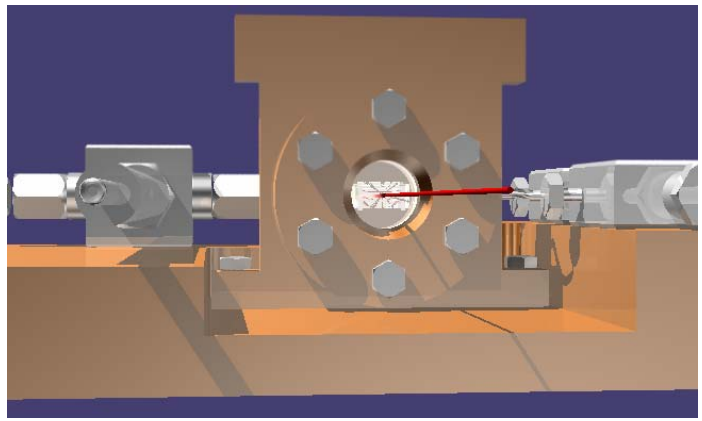
i) fluid cell unit

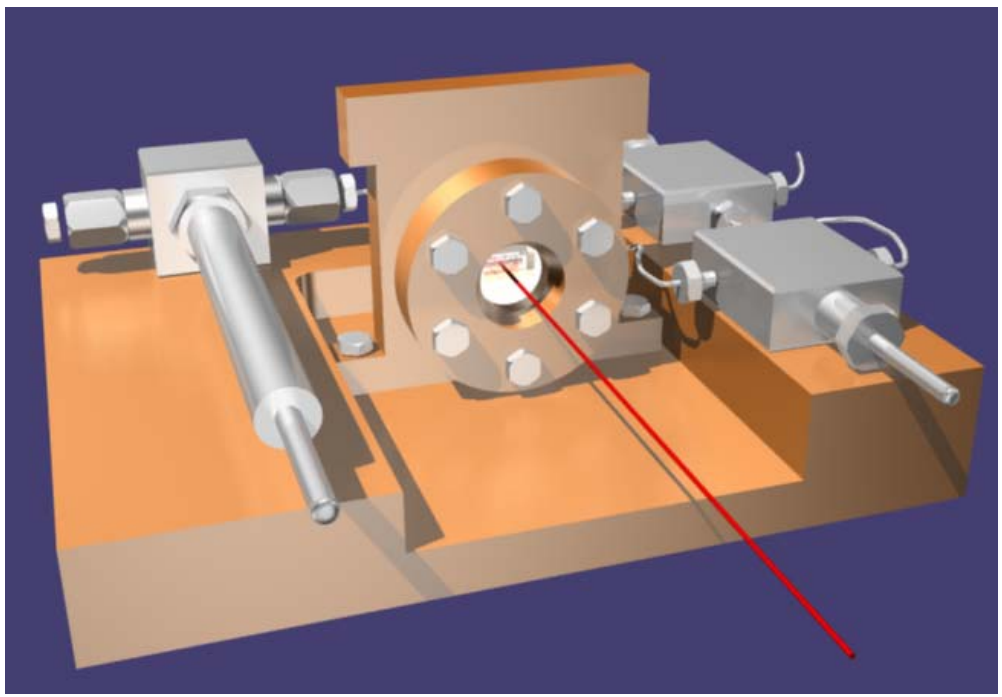
ii) temperature controlling and measuring unit

iii) optical measuring unit

Overview of a fluid cell system

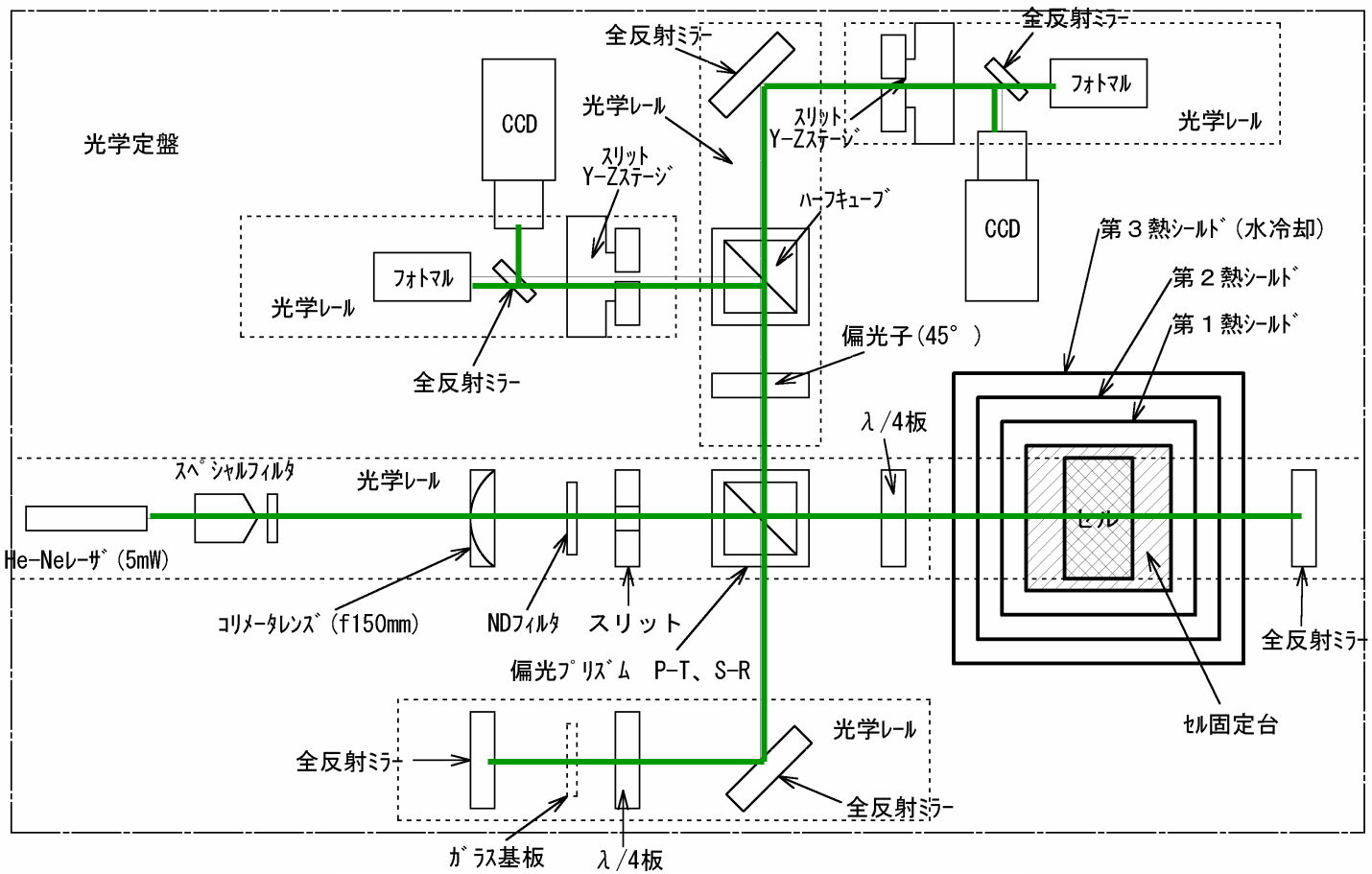






Optical measurement system

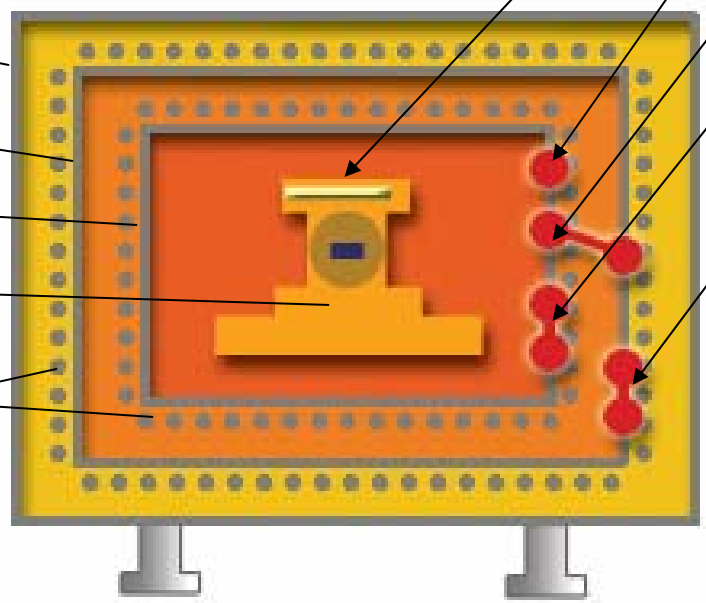
Mach-Zehnder type　　2-d detection by CCD
2-point precise measurement by photo-multiplier



Optical measurement system

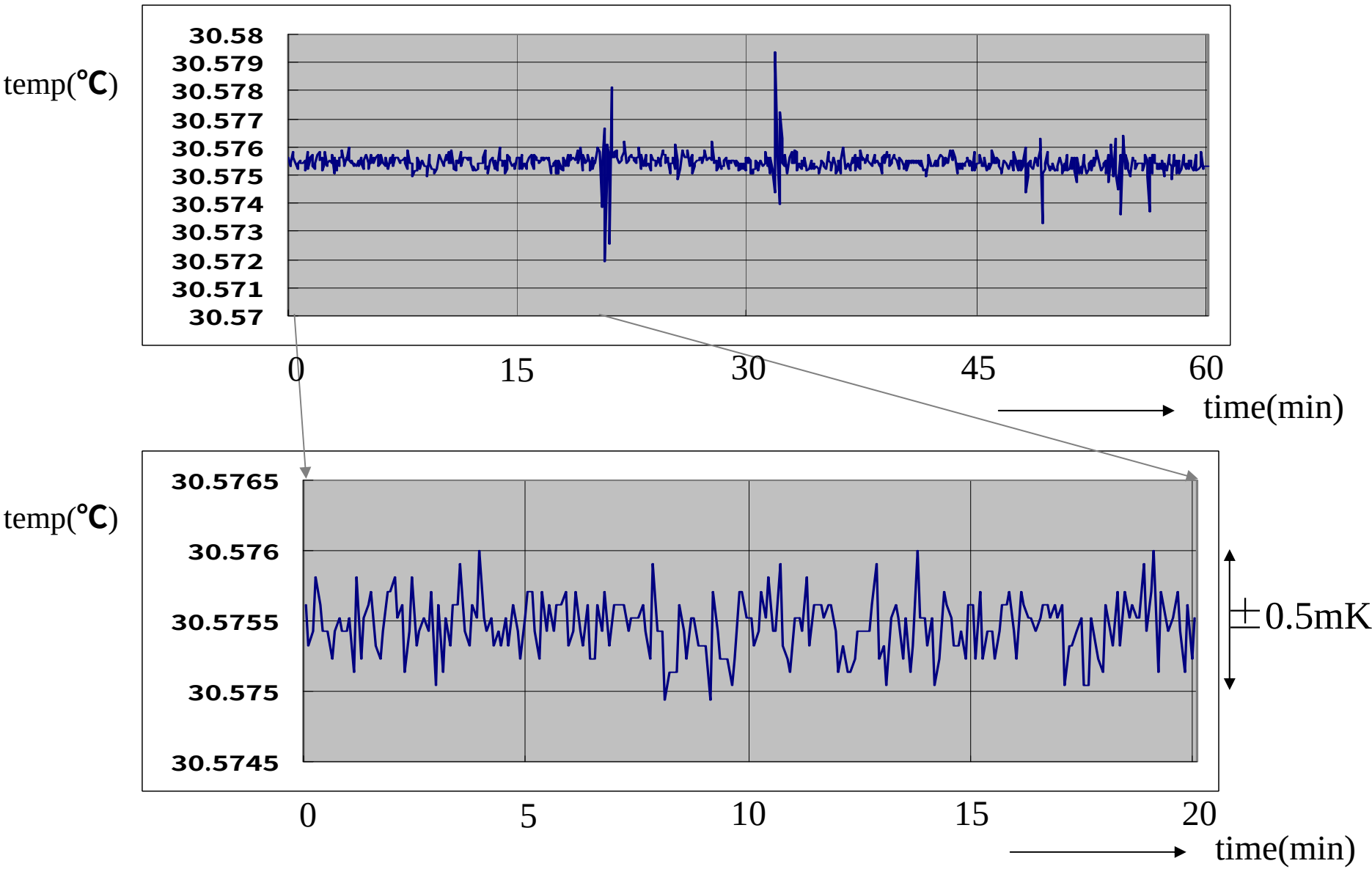
Temperature controlling system

unit		circuit	objective
measure	Absolute temp.	Pt thermometer + low frequency ac double bridge	●fluid cell temp.
control	Absolute temp.	Pt thermometer + temperature meter + PID controller + dc power supplier	●first shield temp.
control	Relative temp.	Chromel-constantan themocouple + μDC amplifier + PID controller + dc power supplier	●temp. difference between 1 & 2 shields ●temp. difference inside of first shield ●temp. difference inside of second shield

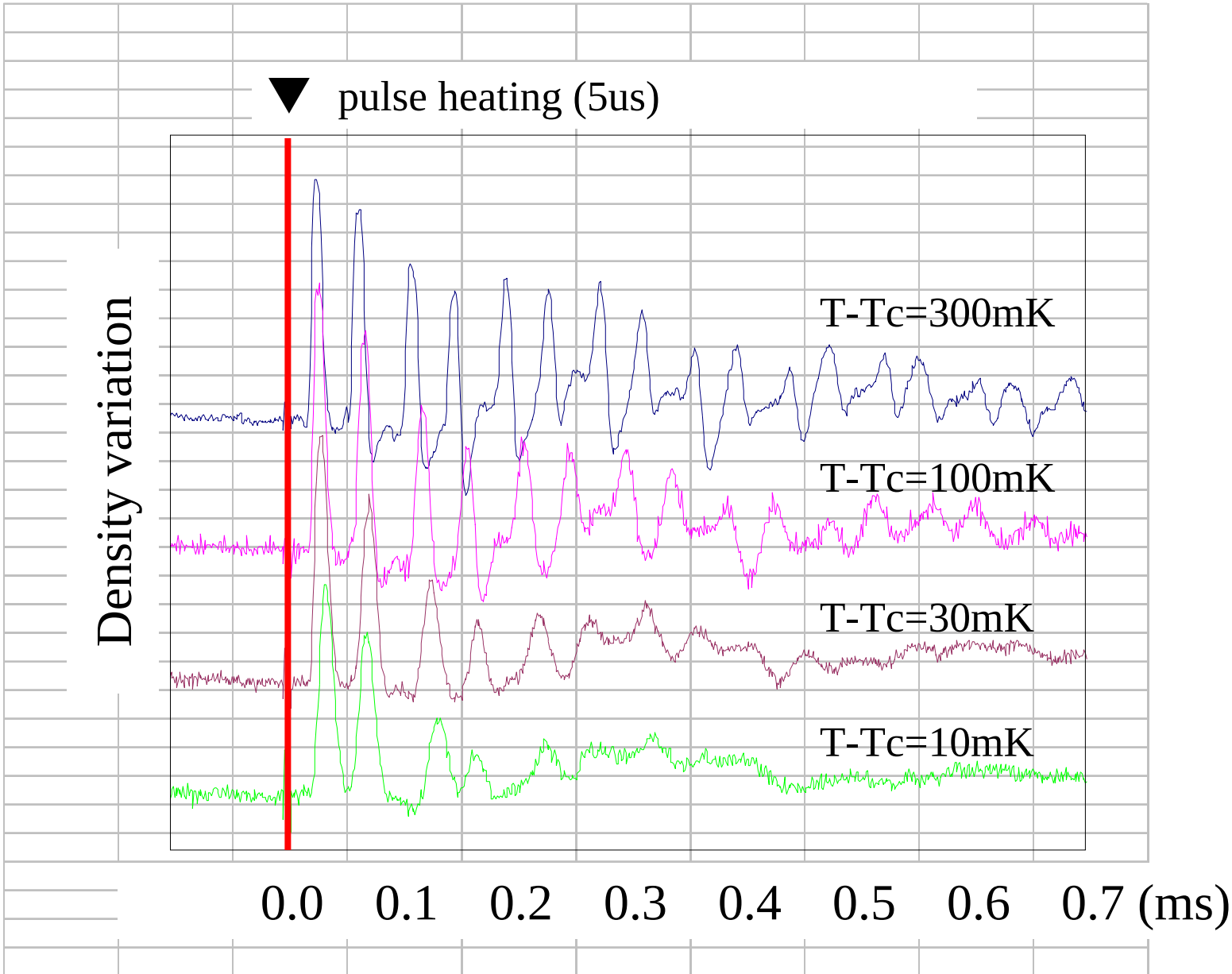


isothermal triple-shell chamber

Absolute temperature measurement using a dummy cell

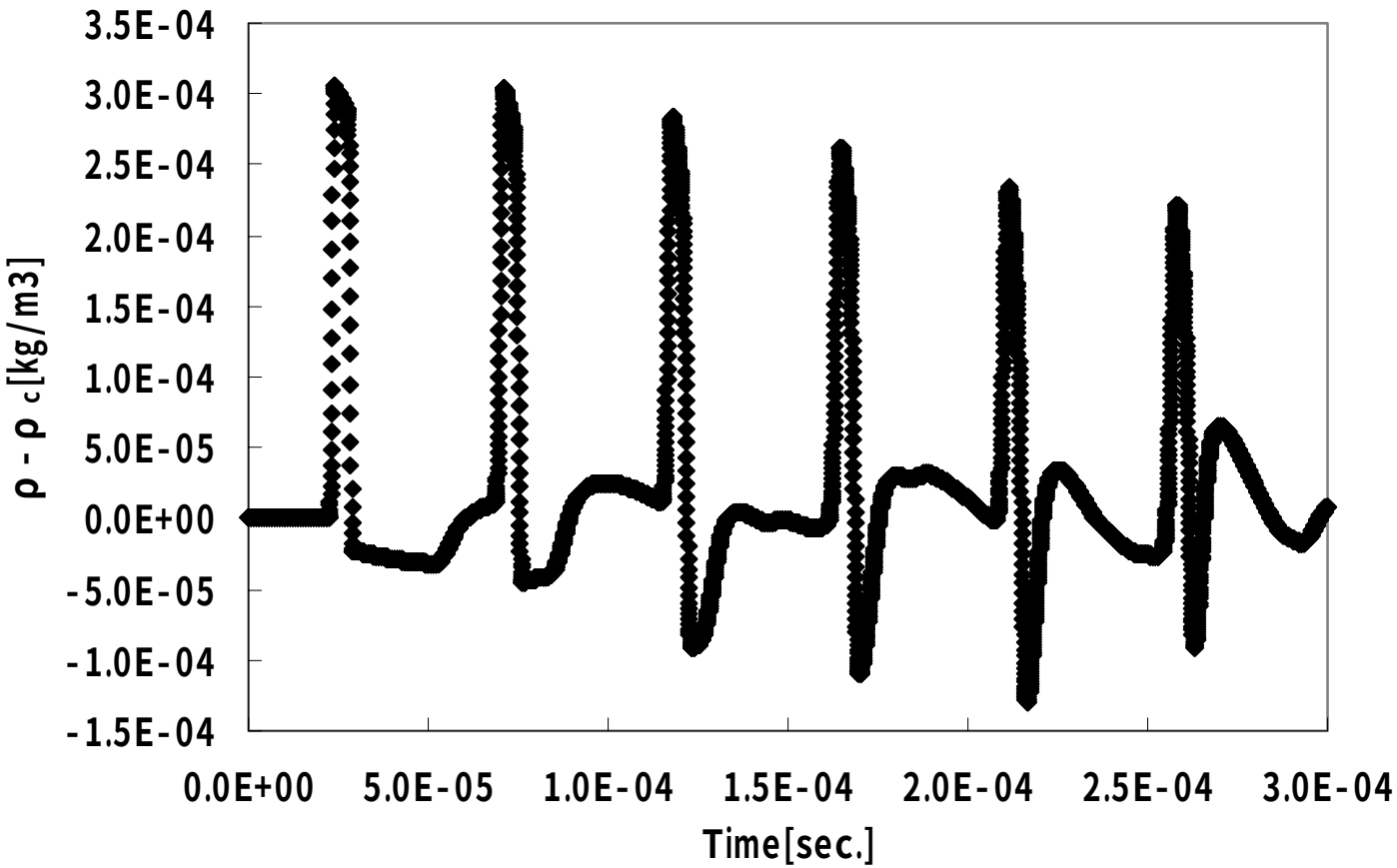


Observation of the ‘piston wave’



2-d numerical simulation

T-Tc=50mK



Summary

Research for elementary processes of the piston effect:

i) High-precision temperature controlling

ii) High-resolution optical measurement

iii) Pulse heating

=> detection of an elementary process

for the piston effect

***Numerical simulations reproduce experimental results.**

Future plan

Future plan:

Flight experiment of the piston effect using TEXUS in 2008 (TBD)